ASPECT Operations Plan
for the Ambrosia Radiological Survey

U.S. EPA Region 6
U.S. EPA NDT ASPECT Team

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Situation. The US Environmental Protection Agency Airborne Spectral Photometric Environmental Collection Technology (ASPECT) has been tasked by the US EPA Region 6 activities to conduct a radiological survey in the Grants, New Mexico area. The survey area consists of a rectangular survey area 5 miles by 8 miles. The survey is scheduled to occur the week of 22 August 2011 and will require three days to complete. This Operations Plan details the components of the ASPECT Program and defines the roles and responsibilities of the participants involved in the survey.

ASPECT System Description. The ASPECT components are installed and operated from an airplane capable of providing 24/7 chemical and radiological detection and can be forward deployed or respond to any location in CONUS. The ASPECT aircraft consist of an AeroCommander 680FL with tail number N742W (Figure 1). The aircraft is white with blue strips and has bold black US EPA lettering on both the top and bottom of the wings.

The system uses two chemical sensors and a radiological sensor to detect and track chemical plumes and radiological sources and deposition. The ASPECT chemical sensors include a high resolution multi-spectral infrared line scanner that produces a two dimensional image and a point detection Fourier Transform Infrared Spectrometer that can be used to obtain detailed chemical information of any

Figure 1 -- ASPECT

point in the plume. Radiological detections are made using a multi-detector sodium iodide sensor using full geospatial registration.

ASPECT provides a preliminary indication of the chemical composition and/or nature of a radiological release within 3 minutes with independent confirmation in 15 minutes. The results are communicated directly to the OSC for further analysis. Additional information on the ASPECT and the aircraft are listed in Appendix B.

General Concept. The survey time-line is provided in appendix A. The aircraft is normally based out of Waxahachie, Texas and will be relocated and operated from the Santa Fe Regional airport during the survey. During all airborne activities, the State of New Mexico hanger located at the airport will be used as the base of operation and primary data processing center.

The ASPECT deployment is in support of Region 6 and all data will be routed according to Region 6 procedures. Data products consisting of radiological products and visible imagery products will be generated by the aircraft. Radiological data will be processed while the aircraft is on station using both onboard automated software and ground-based software tools. A satellite system will be used to transmit selected radiological data to the ground team while the aircraft is in flight status. Once the aircraft returns from a given mission, all data will be downloaded, examined for quality assurance (QA), and fully processed. The Region 6 Project Manager (PM) will have complete access to all data (tentative and final) and will be the data custodian for all released information.

Communications and Contact Information. Logistical communication procedures, conference bridge information and ground to air frequencies are detailed in Appendix D. Appendix E contains detailed information for contacting key individuals during the deployment. Data will be available at the FTP site and via a Google Earth KML as described in Appendix C.

Appendixes:

A - Deployment Timeline
B - Detailed ASPECT Technical Data
C - Digital Data Retrieval
D - Communications
E – Contact Information
F - Proposed ASPECT Flight Plans and Profiles

Appendix A
Deployment Time Line (Details TBD)

21 Aug 11	- Data team travel to Santa Fe
22 Aug 11	- Aircraft travel to Santa Fe - Data Team sets up ground operations
23 Aug 11	- Fly first half of survey - Review of collected data by thedata team
24 Aug 11	- Fly second half of survey - Conduct photo survey - Final review of data by the data team
25 Aug 11	- Weather survey contingency - QC of all rad data - Aerial images processed by the data team
26 Aug 11	- Demobilization of aircraft and data team

Appendix B
Detailed ASPECT Technical Data

The ASPECT sensor suite is mounted in a fixed wing aircraft and uses the principles of remote hazard detection to image, map, identify, and quantify chemical vapors and deposited radioisotopes. Chemical plume measurements are made at a rate of about two square miles per minute (Figure 1). The system normally operates at an altitude of 2800 feet above ground level (AGL) and results in a high IR spatial resolution of 0.3 meters. A simplified system diagram is provided in Figure 2. The radiological data is collected between 300 and 500 feet AGL with a collection time of once per second and a field of view about 600-1000 feet.

Supporting data includes high-resolution aerial digital photography and digital video that are concurrently collected with chemical and radiological data and forms the basis for a geographical information system data cube with several layered data products (Figure 3). Efficient mission execution requires that data is processed on-board the aircraft for transmission or hand-off to the first responder. To facilitate data transmission while in flight status, the aircraft is equipped with a broadband high-speed satellite data communications system. With a combination of onboard data processing and the satellite communication system, selected airborne situational data sets are ready for dissemination to the incident command team in less than 5 minutes after collection.

FIGURE 1 – Sensor Suite

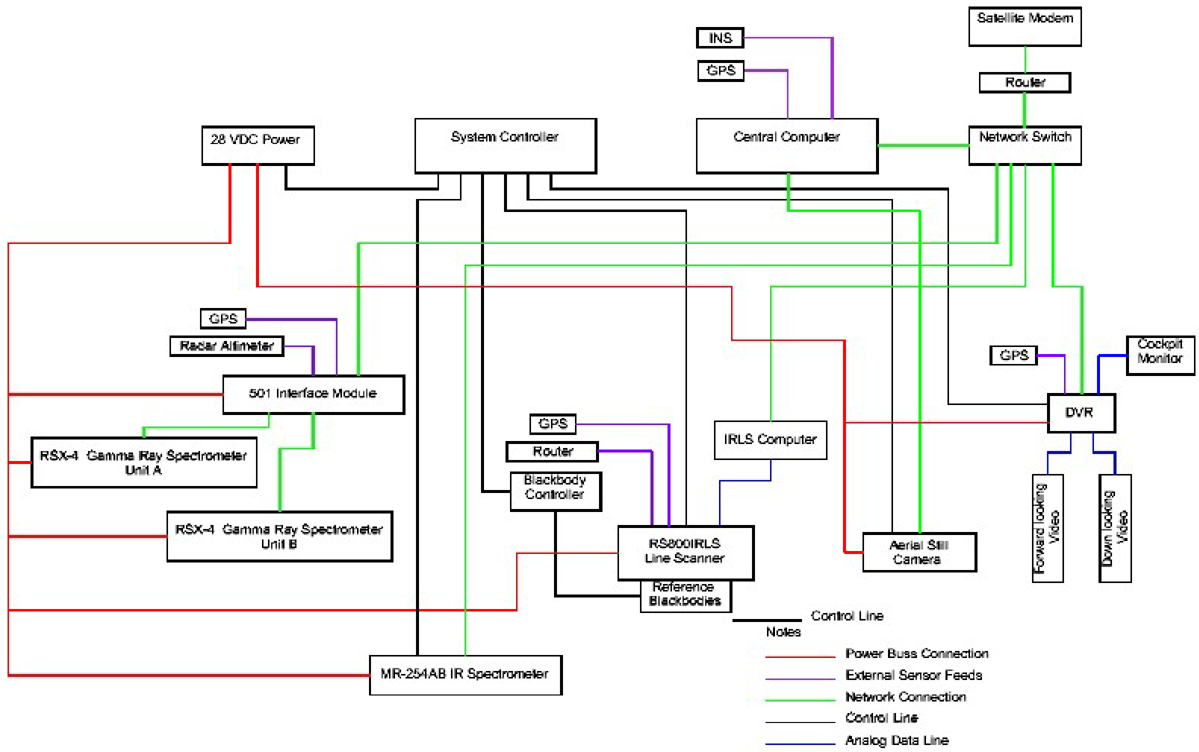

FIGURE 2 - Simplified ASPECT System Diagram

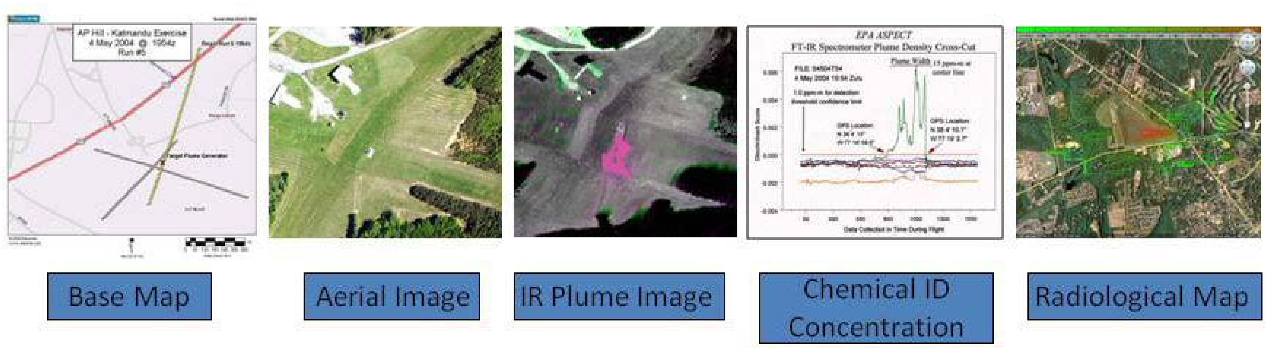

FIGURE 3 – Data Products

1. Airframe

The ASPECT sensor suite is operated from a twin engine AeroCommander 680FL aircraft (Figure 4). The aircraft and crew are certified for full IFR flight operations. This aircraft is equipped with two 21-inch belly holes with retractable bay doors. All sensor systems are mounted on two vibrational isolated base plates positioned over the belly holes. The aircraft can operate from any airport having a 3000 ft runway and can stay aloft for 5 hours. Technical specifications for the program airframe are contained in Table 1.

Figure 4. N742W

TABLE 1 - N742W Technical Specifications

Tail:	N742W
System:	Twin Engine (Reciprocating) Propeller Driven Aircraft
Make:	Rockwell AeroCommander 680 F/L, Part 91 Certification
Power Plants:	Lycoming TGSIO-540-B1, 350 HP each side
Empty Weight:	6585 lbs
Useful Weight:	1915 lbs
Maximum Take-off Weight:	8500 lbs
Typical Cruise Speed:	180 Kts
Typical Flight Duration:	3.75 Hours (65% Power) Plus 45 Minute Reserve
Service and Ceiling:	Low Altitude Waiver, 24000 Ft (MSL) max altitude
Cabin:	Un-pressurized, Crew Oxygen
Portals:	Two 21 inch STC Camera holes with Remote Doors
Avionics	GPS IFR Package Terrain/Obstacle Avoidance Equipped Radar Altimeter Equipped Live Weather Feed Dual VOR Equipped Dual Comms Equipped Dual Transponders
Electrical Buss:	28 vdc @ 200 amps full load
Data Communication:	Phased Array Satellite System, 40-60 KB/sec Data Rate Satellite Telephone, 32kps Data Rate
Readiness Status:	24/7

2. Chemical Detection Capabilities

The principle of remote detection, identification, and quantification of a chemical vapor species is accomplished using passive infrared spectroscopy. Most vapor compounds have unique absorption spectral bands at specific frequencies in the infrared spectral region. An asymmetric stretching between two atoms in a molecule results in a fundamental frequency of vibration. Passive infrared measurements of a vapor species are possible due to small thermal radiance differences between the temperature of the chemical plume and a particular infrared scene background (Figure 5). Both the cloud and the atmosphere contribute to the total emitted radiance measured by an infrared sensor. Careful monitoring of the change in total infrared radiance levels leads to concentration estimations for a particular vapor species. Concentration times path length estimations are obtained based on the molar absorptivity for each vapor species.

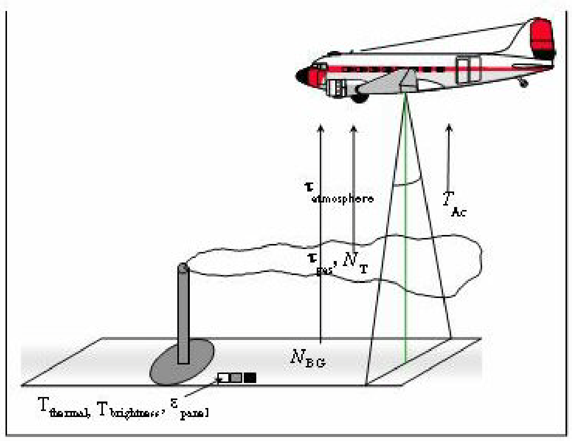

FIGURE 5 - Principles of Remote Infrared Detection

i. Equipment - RS800IRLS Infrared Imager

The ASPECT program uses a modified Raytheon RS800 infrared line scanner to generate wide area chemical imagery (Figure 6). This system incorporates a unique detector assembly consisting of 16 cryogenically cooled optical band pass filters affixed to a focal plan array. Scanning is accomplished with an integrated rotating prism controlled by a feedback motor scan controller. Each rotation of the prism sweeps an angular field of view of 60 degrees resulting in 1500 data points. When the scan rate is coupled to the normal 110-knot ground speed of the aircraft, a scan swath of 0.5 meters is collected. This collection geometry outputs a square data pixel 0.5 X 0.5 meters square. Radiometric calibration is performed during each prism rotation by viewing two reference blackbodies mounted on either side of the unit. Image registration is accomplished during post processing by incorporating pitch and roll data collected from an integrated gyroscope mounted on the scanner body. An integrated GPS receiver is used in the processing step providing geo-registration of each pixel in the finished image product. Detailed specifications of the RS800IRLS are contained in Table 2.

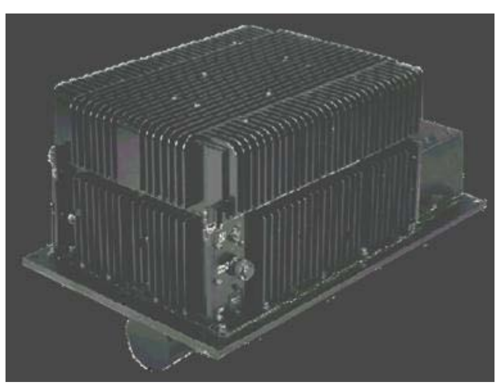

FIGURE 6 - RS800IRLS Line Scanner

TABLE 2 - RS800IRLS Technical Specifications

System:	TI Systems/Raytheon RS800 MSIRLS
Detector:	Cryogenically cooled focal plane array with integrated cold optical filters
Spectral Coverage:	3 – 5 micrometer (mid-wave) and 8 – 12 micrometer (long-wave)
Number of Spectral Channels:	16 total, 8 mid-wave and 8 long-wave
Spectral Resolution:	5 to 20 wave numbers, channel dependent
Spatial Resolution:	Better than 1.0 mill radian
Scan Rate:	60 Hz
Radiometric Calibration:	Two flanking blackbody units
Field of View (FOV):	60 Degrees
Thermal Resolution	0.05 Degree C.
Linear Range	0 to 200 Degree C
Pixel Resolution (IFOV):	0.5 meters @ 850 meter collection altitude (AGL)
Cross Field Scan Coverage:	980 meters @ 850 meter collection altitude (AGL)
Attitude Stabilization:	25 Hz pitch and roll providing stabilized video
Power:	28 vdc @ 10 amps full load
Weight:	27 Kg (60 lbs)
Spin-up Time:	Less than 12 minutes (including cyro-system)
Standard Outputs:	2 Channels of stabilized RS-170 video, 16 channels of digitized (16 bit) spectral data, 1 channel of GPS (2 Hz)
Data Processing	1 step full radiometric image generation using an onboard algorithm. Approximately 1 minute processing time.

a. IRLS - Chemical Image Processing

Processing of chemical data is divided into two broad categories including image processing and spectral processing. Infrared chemical signatures present a challenge in data processing due to the small signal to noise ratio (SNR) of the chemical vapor between the sensor and the surface. It is not uncommon to have a SNR of less than four in a typical vapor cloud. In order to image such a weak signal, the collection system and detector must be optimized for high collection efficiency and a small instantaneous field of view. The ASPECT RS800IRLS meets both of these requirements by using an F 1 high-speed optical train coupled to a 16-channel cold optical filter focal plane array. This configuration provides very high signal throughput while maintaining a 1.0 mill radian spatial resolution. The use of cold optical band pass filters directly mounted on the face of the focal plane array eliminates a large portion of the self-radiance (noise) while minimizing the attenuation of wanted signal content. Raw data is fully radiometrically calibrated using a set of flanking blackbodies providing radiance-adjusted imagery. Jitter removal and band registration are accomplished using an automated algorithm using an integrated 2 dimensional gyro and GPS feed. Final data is generated using an automated geo-registration algorithm in either a geo-Tiff or a geo-Jpeg format. Processing can be accomplished while in flight and requires about 30 seconds to 1 minute per image depending on size. The completed imagery is compressed and made available to ground user through the aircraft satellite link.

The vapor cloud, shown in Figure 7, is an infrared image collected by the RS800SIRLS multispectral sensor at an industrial site in the Midwest. The detection limit of the vapor concentration (shown in red) was determined to be less than 20 ppm/m while the center cloud concentration was greater than 250 ppm-m. This image has been cropped with only 1/3 of the actual sensor field-of-view being displayed. The original image width of the image was approximately 1200 meters wide. For the

ASPECT application, the RS800IRLS system provides a qualitative indication of the presence or absence of a particular chemical species. The detection limit provided by the sensors is applicable to both chemical emergency response and crisis mitigation following a terrorism event.

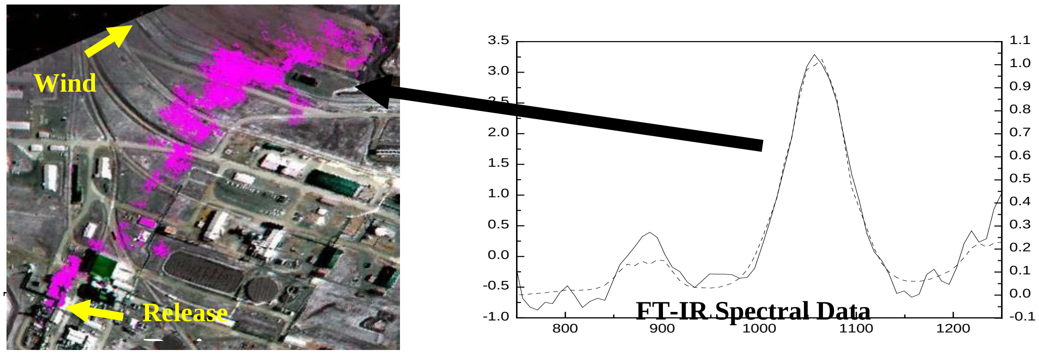

Figure 7 - RS800IRLS Data Product

ii. Equipment - MR254AB Spectrometer

Chemical vapor detection and quantification is accomplished using a modified Bomen MR254AB spectrometer (Figure 11). This custom designed spectrometer utilizes a double wishbone pendulum interferometer providing both high signal throughput and vibrational noise immunity. Two cryogenically cooled detectors provide both mid and long wave operation. Spectral resolution is selectable and ranges from 1 to 128 wave number with 16-wave number normally used for automated compound detection. When operated at 16 wave number resolution, the unit scans at 70 Hz providing a spatial sampling interval every 0.75 meters along the ground track of the aircraft. The program uses an automated compound detection algorithm based on digital filtering and pattern recognition. Geo-registration of each Fourier Transform Spectrometer (FTS) scan is accomplished using a concurrent GPS input from the ASPECT main GPS receiver. Technical specifications of the FTS system are contained in Table 3.

FIGURE 11 - MR254AB FTS Spectrometer

TABLE 3 - FTS Technical Specifications

System:	Modified Bomem MR-200 Series (MR-254AB)
Detectors:	Cryogenically cooled Single Pixel Design
Spectral Coverage:	InSb Detector for 3 – 5 micrometer (mid-wave) MCT Detector for 8 – 12 micrometer (long-wave)
Noise Figure	Mid-wave $6x10^{-9}$ W/cm^2-$srcm^{-1}$, Long-wave $1.8x10^{-8}$ W/cm^2-$srcm^{-1}$
Spectral Resolution:	1 to 128 wave numbers, User selectable
Spatial Resolution:	5 milli-radian (0.2^o) thru 25.4 cm (10 inch) Primary Telescope, 0.75 meter interval at 110 kts collection velocity
Scan Rate:	70 Hz @ 16 wave number resolution
Field of View (FOV):	3 meters @ 850 meter collection altitude (AGL)
Radiometric Reference	Integrated cold source (77^o K)
Targeting	Calibrated bore camera (Nadir)
Power:	28 vdc @ 8 amps full load
Weight:	40 Kg (90 lbs)
Spin-up Time:	Less than 4 minutes (including cyro-system)
Standard Outputs:	2 Channels of Grams format spectral data (16 bit), 1 channel of RS-170 video.
Data Processing:	1 Step pattern recognition compound detection using onboard algorithms, approx 30 – 60 seconds processing time after data collection.

a. Spectral Processing

Spectral data processing (signal processing) from the ASPECT MR-254AB spectrometer is processed using background suppression, pattern recognition algorithm. Processing spectral data from a moving airborne platform requires unique methods to balance weak signal detection sensitivity, false alarm minimization, and processing speed. The background suppression, pattern recognition methods associated with the ASPECT program have been documented in over 100 open literature publications.

One of the principle weaknesses of airborne FTS data is the ability to reference each collected spectra to a suitable background for subsequent spectra subtraction. While methods have been devised to accomplish this procedure, typical airborne spectra show changes between successive scan of several orders of magnitude due to changing radiometric scene conditions. These scan-to-scan changes render traditional background subtraction methods unusable for weak signal detection. The background suppression method used by ASPECT circumvents this problem by using a digital filtering process to remove the background component from the raw interfrometry data. This approach is analogous to using the tuning section of a radio receiver to preselect the portion of the signal for subsequent processing. The resulting filtered intermediate data maintains the weak signal components necessary for subsequent analysis.

An additional weakness of traditional FTS processing involves the need to provide a resolution high enough to permit compounds exhibiting narrow spectra features to be matched with published library spectra. This method is initiated using the Fast Fourier Transform (FFT). While the FFT algorithm is very robust, mathematically certain data collection requirements must be met to permit the transform to be valid. In order to provide high spectral resolution spectra, the length of the interferogram must be matched to the desired resolution for the transform to work properly. This requirement forces a long collection period for each interferogram and since the aircraft is moving, it is probable that the radiometric scene being viewed by the spectrometer will change during the collection of the interferogram. The changing scene causes the FFT to generate spectral artifacts in the resulting spectral information. These artifacts are phantom signals that confuse and complicate subsequent compound identification.

The standard matched filter compound discrimination method likewise exhibits weak signal performance and often generating false alarms due to common atmospheric interference. ASPECT solves these problems by using a combination of digital band pass filtering followed by a multi-dimensional pattern recognition algorithm. The digital filters and pattern recognition coefficients are developed using a combination of laboratory, field, and library data and folded into a training set that is run against unknown data.   Digital filters can be readily constructed which take into account both spectrometer line shapes and adjacent interferents greatly improving the weak signal system gain. The pattern recognition algorithm processes the filter output in a multi-space fashion and enhances the selectivity of the detection.   These methods are very similar to a superhetrodyne receiver that uses band pass adjustable intermediate filters followed by a DSP detector/discriminator such as in a modern radar system. Since the methods use relatively simple computational operations, signal processing can be accomplished in a few seconds. Finally, as data is processed, the position of the detection is referenced to onboard GPS data providing a GIS ready data output. Table 4 lists the compounds that are currently installed in the airborne library using the digital filtering/pattern recognition method.

TABLE 4 - Chemicals Contained in the ASPECT Airborne Library

Acetic Acid	1,1-Dichloroethene	Methyl Acetate	Nitrogen Mustard
Acetone	Dichloromethane	Methyl Ethyl Ketone	Phosgene
Acrolein	Dichlorodifluoromethane	Methanol	Phosphine
Acrylonitrile	Difluoroethane	Methylbromide	Tetrachloroethylene
Acrylic Acid	Difluoromethane	Methylene Chloride	1,1,1-Trichloroethane
Allyl Alcohol	Ethanol	Methyl Methacrylate	Trichloroethylene
Ammonia	Ethyl Acetate	MTEB	Trichloromethane
Arsine	Ethyl Formate	Napthalene	Triethylamine
Bis-Chloroethyl Ether	Ethylene	n-Butyl Acetate	Triethylphosphate
Boron Tribromide	Formic Acid	n-Butyl Alcohol	Trimethylamine
Boron Triflouride	Freon 134a	Nitric Acid	Trimethyl Phosphite
1,3-Butadiene	GA (Tabun)	Nitrogen Trifluoride	Vinyl Acetate
1-Butene	GB (Sarin)	Phosphorus Oxychloride	
2-Butene	Germane	Propyl Acetate	
Carbon Tetrachloride	Hexafluoroacetone	Propylene	
Carbonyl Chloride	Isobutylene	Propylene Oxide	
Carbon Tetraflouride	Isoprene	Silicon Tetrafluouride	
Chlorodifluoromethane	Isopropanol	Sulfur Dioxide	
Cumene	Isopropyl Acetate	Sulfur Hexafluoride	
Diborane	MAPP	Sulfur Mustard	

A unique feature of the ASPECT system includes the ability to process spectral data automatically in the aircraft with a full reach back link to the program QA/QC program. As data is generated in the aircraft using the pattern recognition software, a support data package is extracted by the reach back team and independently reviewed as a confirmation to data generated by the aircraft.

Figure 12 shows airborne absorbance spectra of ammonia vapor collected from an ammonium nitrate fire using the MR-254AB spectrometer. This spectrum was generated by carefully selecting a suitable background spectra and conducting a traditional background subtraction, a time consuming operation. Figure 13 shows the same data processed using the automated background suppression/pattern recognition method. Ammonia detection is clearly demonstrated. Figure 14 shows how these detections are referenced to a real-world geographical map. Individual detection locations corresponding to FTS scans are mated with latitude and longitude coordinate values.

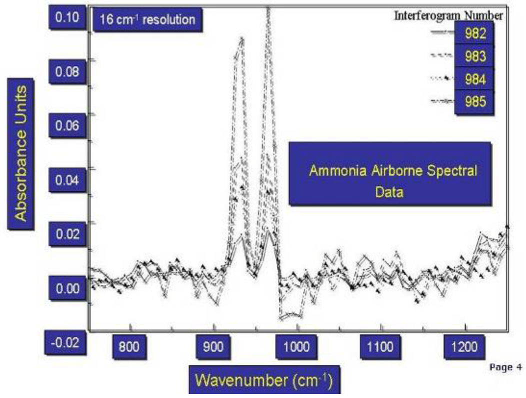

FIGURE 12 - Ammonia Spectra

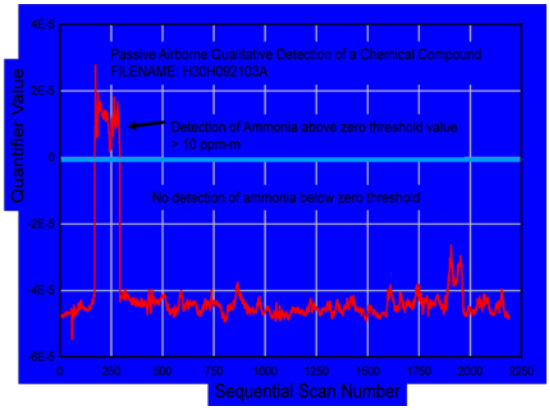

FIGURE 13 - Ammonia Detected with Pattern Recognition

FIGURE 14 - Locations of Ammonia Detection

Quantitative compound specific information is also generated using the MR-254AB spectrometer. This application uses a multi-dimensional model generated using radiometric, thermal, and concentration calibrated laboratory data for each compound in the airborne library. As with compound detection methods, multiple publications have documented the feasibility of using this approach to remotely quantify chemical vapors. The first open literature scientific peer reviewed paper was completed using the ASPECT method.

Figure 15 shows the estimated concentration measured by ground sensors and compared with the remotely collected FT-IR data. The data shows a standard error of prediction of 18 ppm-m for a range of concentration between 20 to 400 ppm-m. This range of concentrations is consistent with both hazardous vapor releases and terrorist concerns.

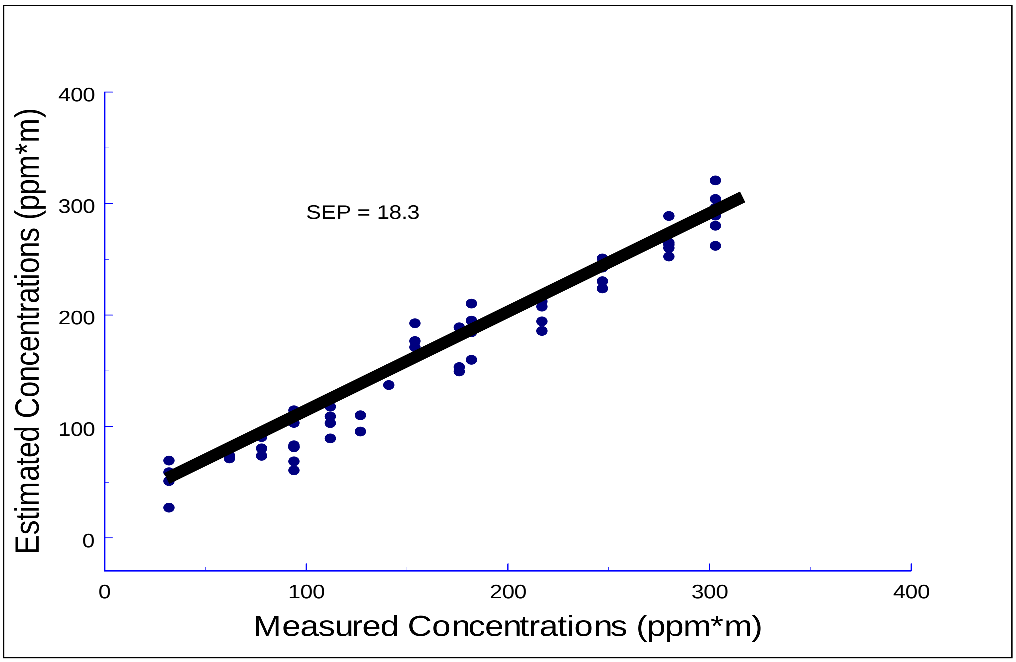

Figure 15. Quantitative Methanol Results

Radiological Detection Capabilities

Airborne radiological measurements are conducted using two fully integrated multi-crystal sodium iodide (NaI) RX4 gamma ray spectrometers (Figure 16). Each RX4 spectrometer contains four 4”x2”x16” doped NaI crystals each having an independent photomultiplier/ spectrometer assembly. Count and energy data from each crystal is combined using a self-calibrating signal processor to generate a virtual detector output. Both spectrometer “packs” are further combined using a signal console controlled by the on-board computer in the aircraft. Due to the advanced signal processing techniques unique to the RX4 units, very high (approximately 1 million counts per second) can be discriminated and processed.

FIGURE 16 - RX4 Gamma Ray Spectrometer

Radiological spectral data, GPS position, and radar altitude are collected at a one-second interval at all times during a survey. In order to provide optimal collection geometry, flight line data is loaded into the aircraft flight computer prior to conducting the survey. Typical airborne surveys are flown at 300 to 500 feet AGL.

Proper spectrometer operation and data quality assurance is maintained using both internal and external calibration algorithms. A self-contained internal calibration algorithm acts as a watchdog and continuously monitors the spectrometer systems for proper system operation and data output. If any errors are encountered with a specific crystal and/or spectrometer pack during the collection process an error message is generated and the data associated with that crystal are removed from further analyses. External calibration procedures are routinely executed and consist of both designed data collection over characterized areas and pad calibrations over known quantities of radiologically doped concrete. Technical specifications for the RX4 gamma ray spectrometers are contained in Table 5.

TABLE 5 - RX4 Technical Specifications

System:	RSI RSX4 Gamma Ray Spectrometer
Detector:	4 Doped NaI Detectors per pack, 2 Packs, 2x4x16 inch crystals.
Energy Coverage:	0 – 3000 KeV
Number of Channels:	1024
Energy Resolution:	Approx 3 Kev per Channel
Scan Rate:	1 Hz
Internal Calibration:	Automatic based on Natural K, U, and T
Field of View (FOV):	45 Degrees
Cross Field Scan Coverage:	700 meters @ 850 meter collection altitude (AGL)
Altitude Determination:	2.4 GHz Radar Altimeter, 10 Meter DEM Database
Power:	28 vdc @ 3 amps full load (2 Packs)
Weight:	90 Kg (200 lbs)
Spin-up Time:	Less than 3 minutes
Standard Outputs:	1024 Gamma Ray Spectra, GPS (2 Hz)
Data Processing	1 Step Full Processing of Total Count, Sigma, and Exposure, Approximately 1 minute Processing Time After Data Collection.

i. Radiological Data Processing

All radiological data is processed automatically using airborne algorithms. Normally, a specifically designed survey flight path is flow by the aircraft and once complete, a spectrum of radiological products is generated from the collected data. Since radiological sources are universally present from the earth and from cosmic sources, all radiological data must be corrected to establish a baseline measurement. Cosmic estimates are established by flying the aircraft 3000 feet AGL while collecting gamma spectral data. At altitudes of 3000 feet and greater all radiological inputs are either from the cosmic sources or the aircraft (which is a constant). Quantified cosmic contributions are stripped out from all subsequent data. Depending on the length of the radiological survey, cosmic backgrounds may be collected at the beginning and end of the survey. In a fashion similar to the cosmic correction, the natural radiological background for the survey area is also established. This process normally calls for collecting a limited amount of data (a test line) at the survey altitude (300 – 500 Ft AGL) in an area of similar geology/land use but outside of the region of survey interest. By subtracting the test line data from the survey data, a corrected radiation map for the survey area is generated.

Several data products are generated automatically by the system including total counts, a sigma map, and an exposure map. The total count product is generated by mapping the corrected total count data (approximately 30 – 3000 KeV) from the spectrometers using the integrated GPS data as the geographic datum. Maps are normally contoured at regular intervals in micro-Roentgens (μR). Figure 17 illustrates a typical survey total count plot.

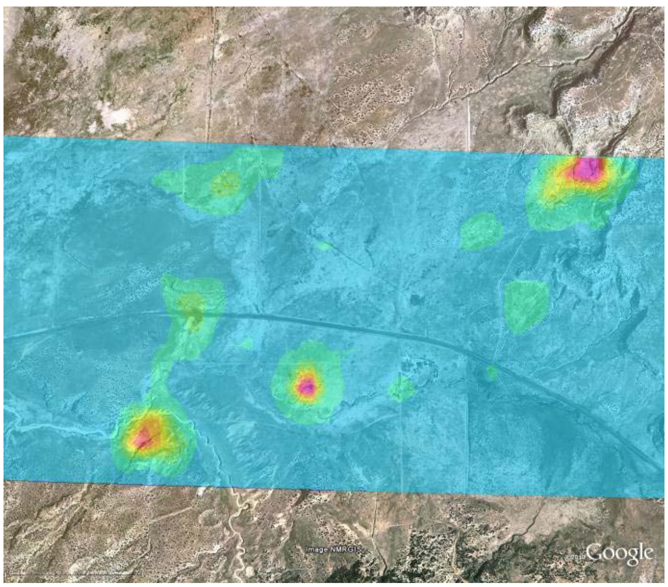

FIGURE 17 - Total Count Plot

A second radiological product includes an array of isotope specific sigma plots or maps. These plots are very useful to the first responder since they help highlight specific data points that may require detailed ground investigation. This procedure consist of a two-step method with the first being a windowing for selected isotope energies followed by a statistical treatment of the data. Isotope specific data is generated by windowing the gamma spectrum at energy levels corresponding to the isotopes of interest. As part of this analysis, higher energy contributions from uranium and thorium are removed using a stripping coefficient. A statistical average and standard deviation is next computed for the entire survey area using the isotope windowed data. Since the standard deviation provides a measure of the variance of the data set, data values showing several standard deviations (sigma) indicate that these values are statistically different from the majority of the population. ASPECT uses a graded scale in which 0 to 4 sigma are considered normal and greater than 4 sigma highlights data very different from the population. Greater than 6 sigma indicates that the data is extremely different and warrants additional investigation. By using different isotope windows, a number of sigma maps can be generated for a given survey (Figure 18).

The final set of products generated by the gamma ray spectrometers consist of an exposure plot or map. This procedure consist of extrapolating the measured total count data collected at the flight altitude down to the total count that would be measured 1 meter above the surface. This method utilizes a weighting algorithm that provides more focus on the high energy counts since these represent the most energetic and penetrating gamma rays. The extrapolation process is accomplished using the calibration coefficients developed as part of the exterior calibration process. The resulting data is plotted in μR/hr and provides the first responder with a health-based estimate of radiological dosage at the ground surface (Figure 19).

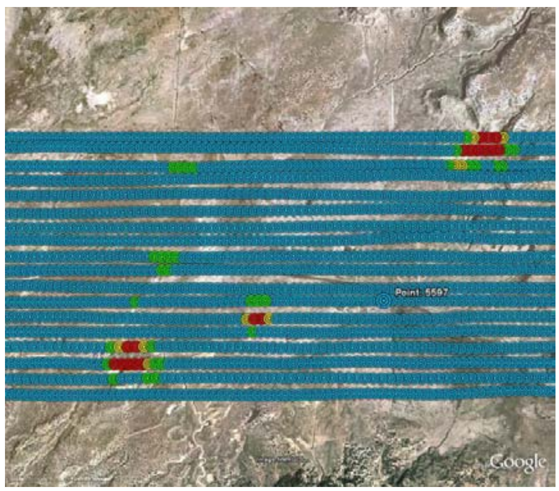

FIGURE - 18 Sigma Plot

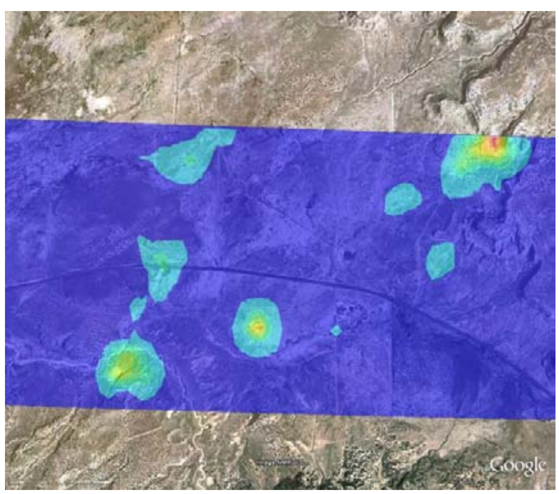

FIGURE 19 - Exposure Plot

4. Visible Imaging Technology

ASPECT utilizes a still digital Nikon DX2 camera to collect and provide visible aerial imagery as part of the core data product package (Figure 20). The DX2 consist of a 12.4 mega pixel CMOS camera supporting a 3:5 aspect ratio frame. The system uses a 28 mm wide-angle lens to provide an image of similar size to the RS800 IRLS generated image. The digital camera is slaved to the primary IR sensors and provides concurrent image collection when the other sensors are triggered for operation. All imagery is geo-rectified using both aircraft attitude correction (pitch, yaw, and roll) and GPS positional information. Imagery can be processed while the aircraft is in flight status or approximately 600 frames per hour can be automatically batch processed once the data is downloaded from the aircraft. Technical specification for the DX2 camera is given in Table 6.

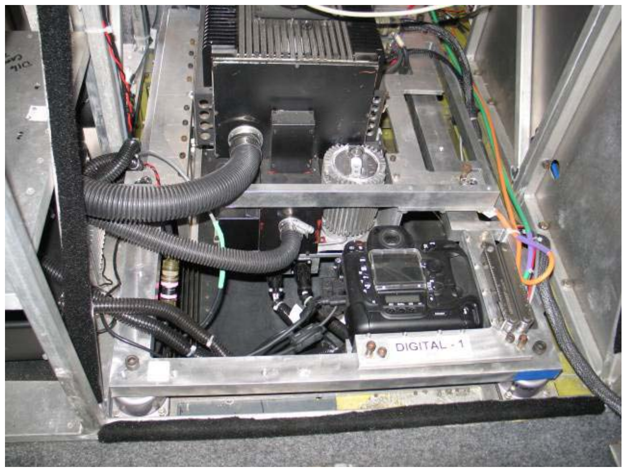

FIGURE 20 - DX2 Aerial Digital Camera

TABLE 6 - DX2 Aerial Digital Camera Technical Specifications

System:	Nikon DX2 Camera Body
Detectors:	12.4-megapixel digital CMOS sensor
Aspect Ratio:	3:5
Lens:	28 mm Digital Compatible
Field of View (FOV):	824 meters Cross flight and 548 meters Direction of Flight @ 850 meter collection altitude (AGL)
Pixel Resolution (IFOV):	19.2 cm @ 850 meter collection altitude (AGL)
Frame Timing and Collection Rate:	Operator Selectable, 3 to 8 seconds, Approximately 600 frames per hour
Trigger Control:	Automatic, Manual, and Slave
Power:	12 vdc @ 1 amp full load
Spin-up Time:	Less than 2 minutes from System Start
Standard Outputs:	JPEG, Tiff
Data Processing:	Full INS/GPS Geospatial Rectification

In order to provide situational information from the perspective of the flight crew, ASPECT also supports an oblique camera system that is operated from the right side of the aircraft. This camera consists of a Canon EOS Rebel digital SLR camera body with a 30 – 120 mm variable zoom lens (Figure 21). Frames are collected at an approximate the 2 o’clock position relative to the aircraft with the target approximately 1000 meters from the aircraft. Table 7 provides technical specification of the oblique camera system.

FIGURE 21 - EOS Oblique Camera

TABLE 7 - Canon EOS Aerial Oblique Digital Camera Technical Specifications

System:	**Canon EOS Camera Body**
Detectors:	**6.3-megapixel digital CMOS sensor**
Aspect Ratio:	**3:5**
Lens:	**30-120 mm zoom, Digital Compatible**
Trigger Control:	**Manual**
Power:	**Internal Battery**
Standard Outputs:	**JPEG, Tiff**
Data Processing:	**Spatial Geo-reference**

i. Visible Imagery Data Processing

Visible imagery collected with the ASPECT system is ultimately processed into a geo-registered jpeg or tiff format image. Image processing is composed of two primary steps including image enhancement and geo-registration. Both of these processing steps can be processed while the aircraft is in flight status but typically, imagery is processed once the aircraft lands due to the large quantity of data involved with aerial photography. A standard flight mission often generates 600 aerial images.

The ASPECT aerial camera consists of a still frame 3x4 ratio digital camera. A wide field of view lens is utilized to match the ground width coverage of the line scanner system. Due to the speed of the aircraft and the fact that ASPECT may fly in low light conditions, the camera uses a fixed focus and shutter speed configuration. Raw imagery is subsequently processed to balance contrast and saturation of each image. In addition, since a wide-angle lens is uses, edge distortion is corrected using a custom-built camera model. Both of these overall algorithms are executed automatically in a batch processing system.

The ASPECT camera is fix-mounted to the primary optical base plate. The camera axis is bore sighted to within 0.5 degrees to the axis centers of the other optical systems. While images are being collected, a concurrent system collects both GPS data and inertial data to provide a high-resolution pitch, roll, and yaw correction dataset. An automatic software package merges these data set and geo-corrects each image using a triangular correction mode. The resulting images statistically show less than 11 meters of center frame positional error and less than 1 degree of rotational error. As with the frame enhancement processing, geo-registration is accomplished in a batch mode at a rate of approximately 800 images per hour. Following registration, images can be directly used by the responder or further corrected with minor positional and rotation corrections (Figure 22).

If requested by the data user, aerial photography (and IR imagery) can be stitched into a wide area mosaic. While this process does take some time, a 4 square kilometer mosaic image (approximately 8 frames) can be assembled in about 2 hours (Figure 23).

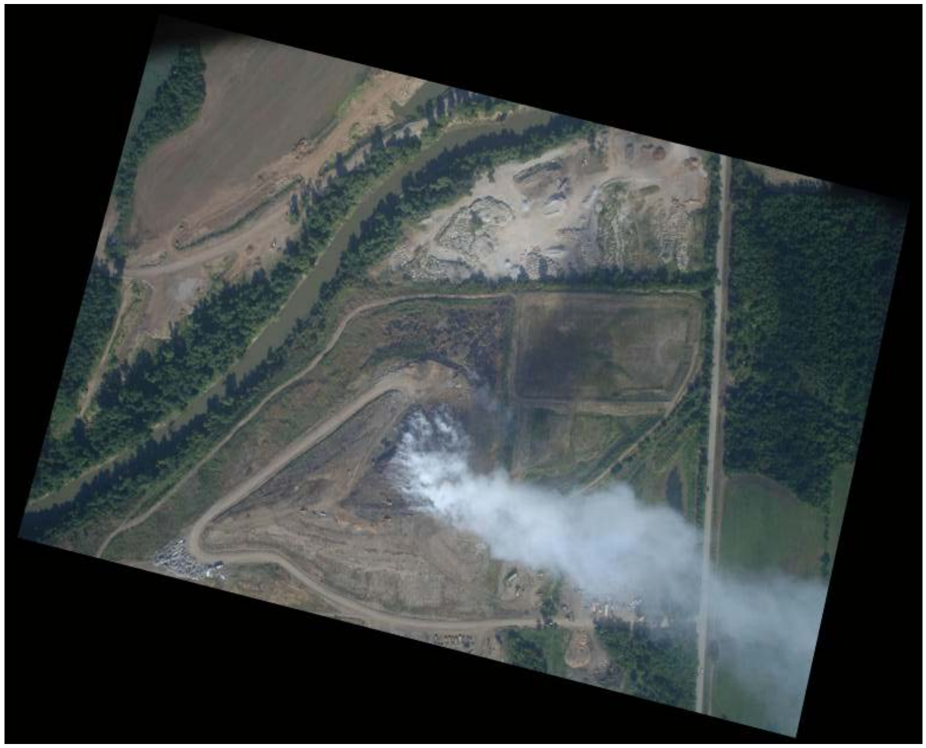

FIGURE 22 - Digital Aerial Visible Imagery

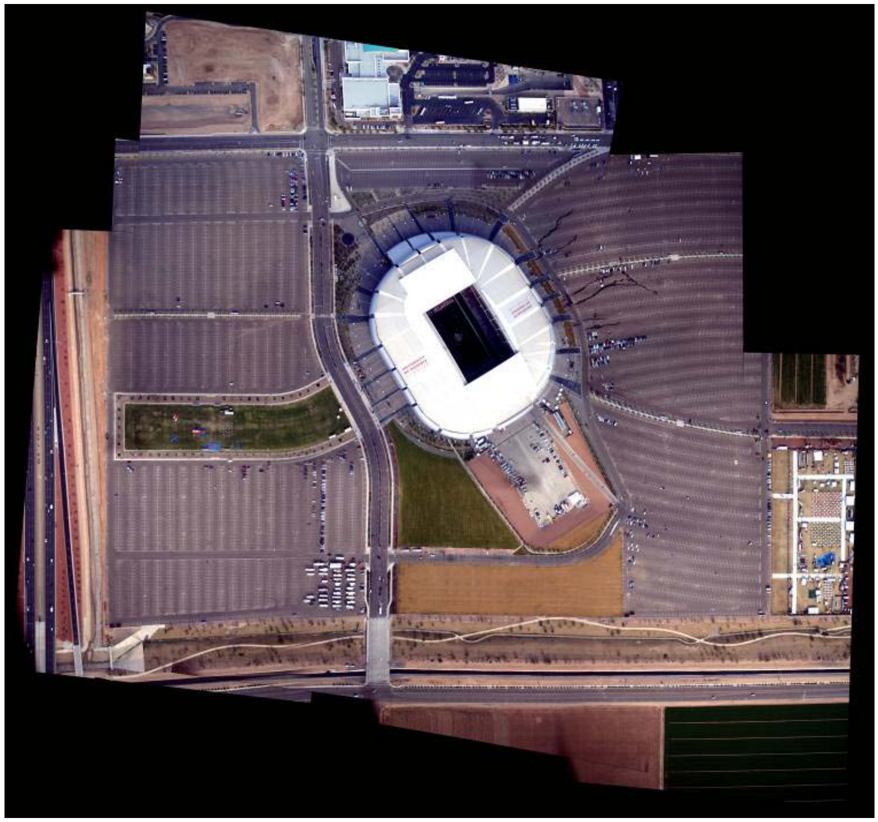

FIGURE 23 - Mosaic Imagery Product

Oblique digital photography is processed to capture the situational environment from the perspective of the flight crew. All frames are collected from the right side of the aircraft at approximately 45 degrees from the nose of the aircraft. During automated processing, GPS data is used to provide the position that the frame was collected and the direction that the frame was collected is determined from the track of the aircraft and the relative direction that the camera was operated from within the aircraft. Figure 24 illustrates an example of an oblique image.

FIGURE 24 - Oblique Aerial Image

5. Data Communication Technology

The ability to rapidly transfer data from the ASPECT aircraft to the ultimate end user is mandatory if the system is to support emergency response functions. ASPECT uses a state of the art Satellite based communication system that provides broadband data through put while the aircraft is in flight status (Figure 25). The system consists of an electronically steered phase array satellite antenna coupled to a RF power amplifier/receiver supporting a wired onboard computer TCP/IP modem/network. All components of the system have been installed and certified as part of a formal FAA STC procedure. The system utilizes a geosynchronous satellite connection and permits full rate communication throughout the contiguous U.S. Table 8 contains the technical specifications for the satellite communications system.

FIGURE 25 - Satellite Communication System Phased Array Antenna

TABLE 8 - Satellite Communication Technical Specifications

System:	Chelton Broadband Satellite System
Antenna:	HGA-7000 Electronically Steered Phased Array Antenna.
Modem:	Integrated Airborne Modem/Router, 100 MB/s data rate
Power Amplifier:	HPA-7400 Bi-directional Power Amplifier/Pre-Amplifier Short Coupled to the Phased Array Antenna.
Data Rate:	Up to 332 kbs (Approximately 60 Kbs) Full Duplex
Constellation Type:	Fixed Geo-Synchronous
Coverage:	Continuous Coverage Over the Lower 48 States.
Certification:	FAA STC
Power:	28 vdc @ 10 amp full load
Spin-up Time:	Less than 2 minutes from System Start
Standards:	TCP/IP

Technical Coordination and Support

The ASPECT data team is located at the Santa Fe Regional airport that will provide data analysis services to support Region 6 for the Ambrosia survey. It is anticipated that the team will be active on 22 August 2011. This data analysis support will provide information in four formats to include: (1) digital data stored on an FTP site, (2) communication through conference lines, (3) hard copy displays, and (4) data presentation and display through Google Earth. Procedures to access this information are provided in Appendix D.

The data team will also provide hardware support to the aircraft sensors, including backup radiological and camera systems. In the event that these systems show faults, the team will exchange the reserve sensors.

Appendix C
ASPECT Data Routing and Retrieval

To support the Ambrosia survey ASPECT will generate data consisting of: (1) visible digital images, (2) Google Earth KMZ which includes all imagery and radiological data products, (3) visible images in a data format capable for import to GIS packages, (4) maps showing the location of flight paths, (5) processed gamma ray data, and (6) data logs containing information about each collected data file.

ASPECT uses onboard data processing to accelerate the delivery of data. Radiological data will be processed while in flight status and a data package will be extracted from the aircraft using the satellite data system. All data will be QA reviewed by the ASPECT Team to make certain that the radiological detection equipment is operating in a proper fashion. Once the aircraft has returned from a mission, all data will be transferred to the reach back data team for final QA and processing. It is anticipated that most data processing will be completed prior to the aircraft and team demobilizing from the site on 26 August 2011.

Data Storage

The raw data collected as part of the survey will be archived at the URL site: ftp.epaaspect2.net (password protected). The file structure in the archive will be the following for both the raw and processed data. The raw data will be under "raw" while the processed data will be under "processed". The standardized files structure used is contained in table 1.

Table 1. Data File Structure

Main subdirectory labeled with Date and Flight number		
File	**Contents**	
DIGITALS	Raw NADAR aerial digital photography data and event (shutter) times.	
GAMMA	Raw gamma spectral data	
GPS	Raw gps positional data and inertial navigation data	
OBLIQUES	Raw oblique aerial digital photography data	
PROCESSED DATA	Processed data consisting of:	
	Processed Digitals	Georectified NADAR color photography
	Processed GAMMA	Georectified Sigma Plot Georectified Exposure Contour Plot Text data package
	MOSAIC	Georectified color photography mosaic
	Processed Obliques	Georeferenced color oblique photography
Reports	Completed mission reports and mission updates	
Run sheets	Scan copies of written in-flight collection logs Mission orders	

Data Distribution

Distribution of data will be under the control of the Region 6 PM. A Google Earth component will be provided to further aid in viewing the data. Direct access to all ASPECT products can be accomplished using a file (KML) accessible via Google Earth. A survey specific id and password protected KML file can be generated if requested by the Region 6 PM.

Operation of Google Earth requires a copy of Google Earth (free or Pro) be downloaded and installed on an accessible computer. The KML link can then be opened via Google Earth permiting full access to all data. This link can also be emailed to user authorized by the Region 6 PM. A brief instruction set on using the Google Earth tool is contained in the following section.

Google Earth Tool Instructions

To expedite data delivery a simplified tool based on Google Earth can be used to disseminate and view geo-spatial data. Use of this tool requires that an up-to-date version of Google Earth (free or Pro) and a suitable web browser (Internet Explorer, Chrome, Firefox, etc.) be installed on the user's computer. Access to all data is facilitated through a small KML file. The following instructions detail how to use the tool:

1. Using your email server download the KML file to your desktop if you received it through email. If provided on a memory stick, simply copy the KML file to your desktop.

2. To open the KML, double click the file located on your desktop. This will automatically bring up your Google Earth program, and the ASPECT airplane icon will appear and zoom to the geographic area of the mission.

3. The ASPECT airplane icon provides total access to all of the data available for the mission. Double Click the airplane and a balloon will expand listing all of the relevant information for this particular ASPECT mission.   The relevant information available may vary from mission to mission. All of the sections depicted in blue are links to data on the ASPECT mission servers. The following is a brief description of each section:

A brief mission description. This section contains details of the overall mission and specific details of the current mission which will open up in a separate browser window. When completed with the section close the browser window to return to Google Earth.

Sensor suite capabilities. This browser window contains a description of the sensors used on ASPECT aircraft. When finished with this section close the browser window.

Color aerial photography. Clicking the color aerial photography section permits georectified NADAR images to be displayed and/or downloaded using Google Earth. Once selected, available images from the last mission will be displayed as transparent outlines on the main screen.

Note: By default, only outlines from the last mission are displayed. Additional images collected on prior missions can be selected under the places menu on the left side of Google Earth.

To load the actual imagery into Google Earth, click on a camera icon in one of the polygons. A photo balloon will open and a thumb nail of the non-georectified photograph will be displayed. Two options are given at the bottom of the image:

Download Image Overlay into Google Earth

Download High Resolution Image into Web Browser

By clicking on the “Download Image Overlay into Google Earth” the image will be imported into the Google Earth imagery database and the georegistered image will be shown on the screen. Repeat this process for as many images as you are interested in. *Note: each time you execute this procedure the referenced aerial photograph frame will appear in blue in you temporary places pane on the left hand side of the Google Earth window.* Should you want to view a full resolution image of this frame, click on the option “Download High Resolution Image into Web Browser”. The full resolution image will be displayed in a separate browser window.

Mosaic Aerial Photography (By Date). Selection of a color mosaic will load a georectified color mosaic into Google Earth. Selected of the appropriate image is referenced to the date of collection. Due to the large size of these files, several minutes may be required to fully download the file.

Oblique Photography. Viewing of oblique color aerial photography is accomplished by selecting the oblique photography item. Once selected, available oblique images for the last flight will be displayed as a collection of arrows. These arrows represent the location that the aircraft was positioned and the direction the camera was pointed when the frame was collected out of the right side of the aircraft. As the curser is moved over the respective arrows, the frame number will be highlighted. If an arrow is double clicked a thumb nail of the image will be displayed. The user has the option of downloading the image in a browser.

Aircraft Flight Tracks (By Date). Flight track information for the last mission is available using this selection. Once selected, a color flight path will be displayed. Multiple tracks can be displayed by selecting additional paths from other missions.

Aerial Radiological Product (By Date), Optional. If directed by the project manager, all radiological products can be included in the Google Earth link. Maps showing total count, sigma, and exposure can be selected in a similar fashion as the other data products.

New Data Additions

As new data is added to the Google Earth KML, the provided Google earth link will permit full access to the new data. You must periodically close the Google Earth program and re-open it again using the Google Earth icon on your desktop. **When you exit the program, Google Earth will prompt whether to save your “temporary places”. Select discard.** Depending on the amount of data being collected and uploaded to the mission server, reloading the Google Earth program once each hour will permit access to the new data.

Trouble Shooting

If you are having problems with multiple ASPECT airplane icons appearing on the screen do the following:

1. Locate the Places Box on the upper left hand side of Google Earth.
2. Locate the line labeled as My Places.
3. Right click on My Places and select Delete Contents
4. Close Google Earth and reopen using the Google Earth Icon on your desktop

Appendix D
Communications

Phone Conference Call Bridge
The ASPECT program has a dedicated 24/7 phone bridge which be used to communicate with the reach back data analysis cell. This line will be made available to Regional personnel to discuss mission progress, data findings and other survey related information.

Phone bridge #: 1-866-299-3188
Code: 5134872423#

Direct Tracking of Aircraft
Due to the nature of the survey, FAA will not provide public tracking of the aircraft during the survey. The aircraft will be providing periodic SPOT tracking data so the location of the aircraft will be known. In addition, the aircraft will provide periodic position track information which will be displayed using Google Earth. This information will be made available as part of periodic status updates on the mission.

Google Earth Link for Data Display
The reach back data team located at the Santa Fe Regional Airport hanger will be processing data collected from the survey and placing it into a format that can be accessed through a Google Earth file. This file will contain processed data and other situational awareness information. A Google script will be provided to the project manager for distribution.

Direct Aircraft Communications
Direct radio communication with the aircraft will be conducted using 123.45 Mhz (AM) during the event and when in range. A suitable radio will be provided by the NDT scientist at the reach back hanger.

Appendix E
Contact Information

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FAA

TBD

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Appendix F
Proposed ASPECT Flight Plans and Profiles

The Ambrosia survey is scheduled to be flown on 22 – 26 August 2011. The Ambrosia area is located approximately 19 miles north of Grants, NM and consists of a rectangular area 5 miles by 8 miles positioned in a northwest to southwest fashion centered on Lake Ambrosia (Figure 1). The area contains a number of uranium mining and processing areas positioned throughout the survey area. The ASPECT aircraft will be used to survey the area in a systematic fashion using a regular altitude and line spacing. For the purpose of this survey, a standard radiological collection altitude of 300 feet above ground level (AGL) will be used. A line spacing of 500 feet will be used. A total of 49 flight lines will be flown and will require approximately two days to complete. Radiological survey flight lines are illustrated in Figure 2.

As part of the survey, a photographic survey will also be conducted over the site and will consist of flying regularly spaced lines in a similar fashion as the radiological design. A standard altitude of 5000 ft AGL will be used with a line spacing of 3000 ft. Eight photo lines will be flown and will generate about 300 digital aerial images. Photographic flight lines are illustrated in Figure 3.

A third day is included in the survey to provide a weather contingency. A summary of operational parameters and the collection schedule is provided in Table 1.

Figure 1. Ambrosia Survey Area

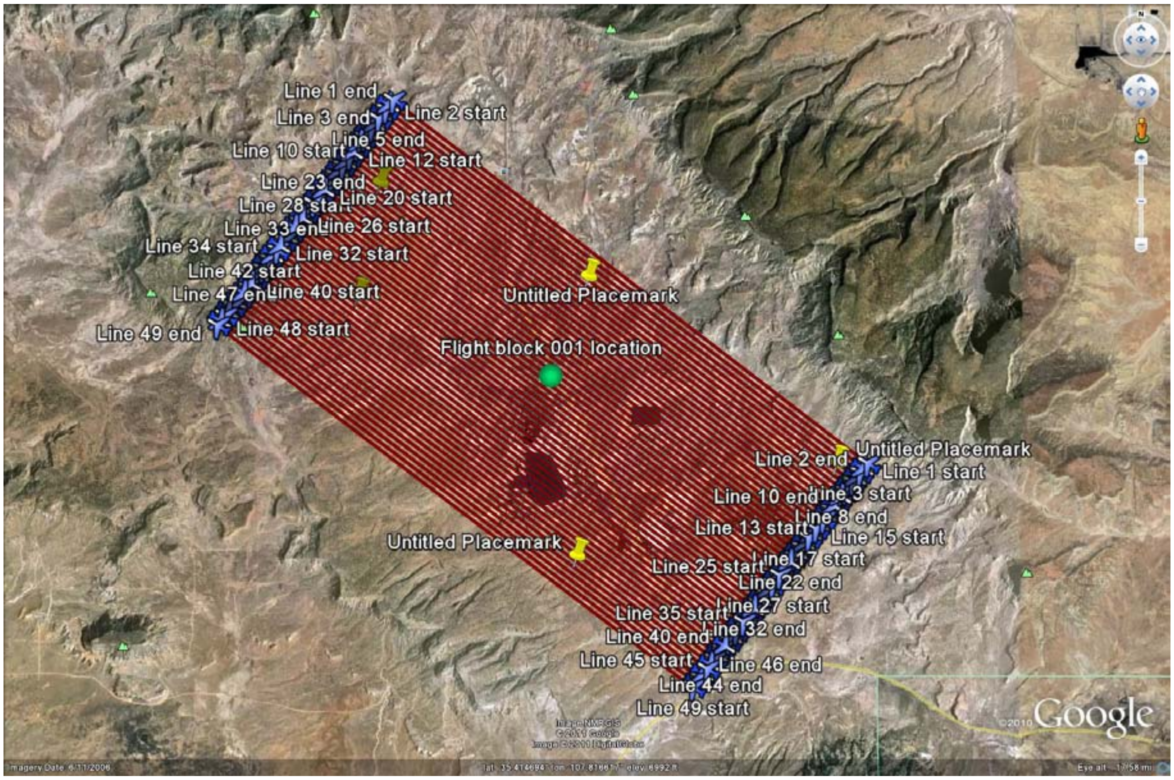

Figure 2. Radiological Flight Lines

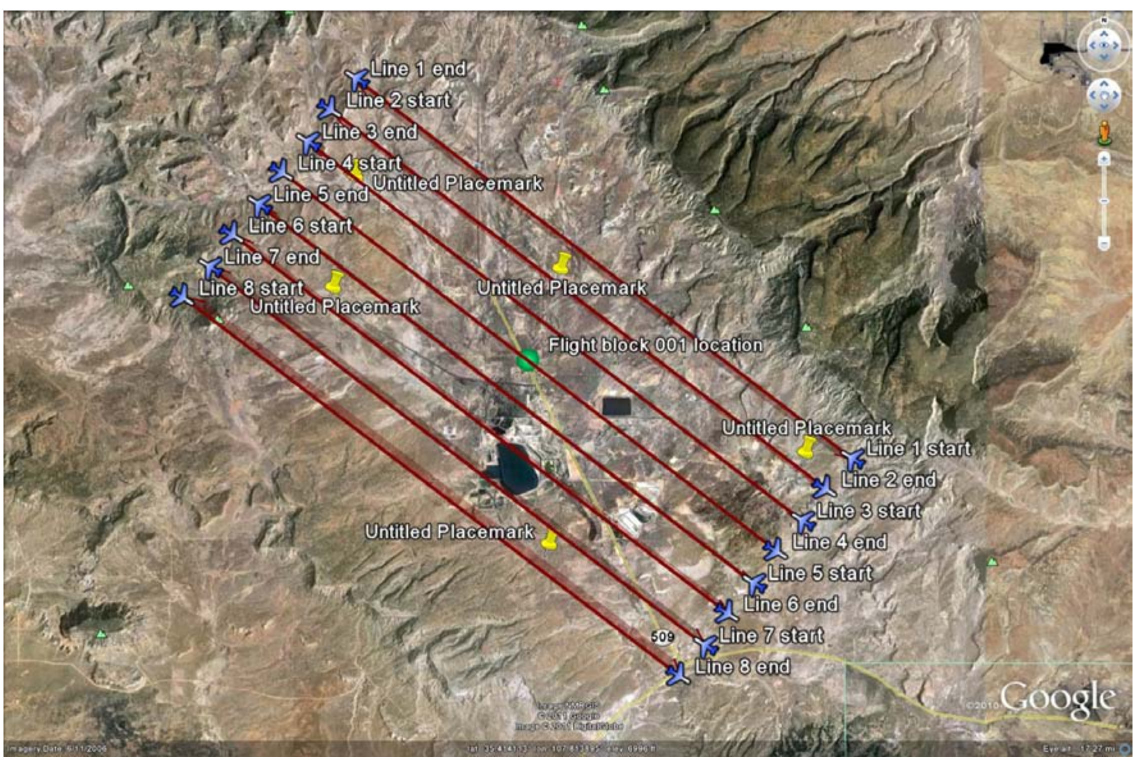

Figure 3. Photo Flight Lines

Table 1. Collection Profiles and Schedule

Collection Type	Altitude	Air Speed	Number of Passes
Radiological	300 Ft AGL	110-120 Knots	49
Aerial Imagery	5000 Ft AGL	120 Knots	9

Survey Type	Date	General Location
Radiological	23 Aug 2011	Ambrosia North Half
Radiological	24 Aug 2011	Ambrosia South Half
Photographic	24 Aug 2011	Entire Survey Area